COMPARATIVE STRATIGRAPHY OF THE LOWER PART OF THE CARBONIFEROUS-PERMIAN BIRD SPRING FORMATION, SPRING MOUNTAINS, CLARK COUNTY, NEVADA

by

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Submitted to the Department of
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ABSTRACT

Two stratigraphic sections of the lower 200 m of the Carboniferous-Permian Bird Spring Formation were examined in the Spring Mountains, Clark County, Nevada. The Bird Spring Formation was deposited in the late Paleozoic Bird Spring Basin. Despite subsequent large-scale east-directed thrust faulting of Bird Spring basin, the two sections lie in the same thrust sheet and have retained their original separation of 40 km.

Thin-section studies reveal five lithofacies common to both areas. The five facies are characteristic of a shallow-marine environment which was subjected to periodic sea-level fluctuations. Facies 1 is a carbonate-cemented siltstone, Facies 2 is a lithified carbonate mud, Facies 3 is a matrix-supported biomicrite, Facies 4 is a grain-supported biomicrite, and Facies 5 is a biosparite. Facies 1 and 2 were deposited in a quiet, anoxic environment, below wave base. Facies 3 was deposited near wavebase in an oxygenated environment, Facies 4 was deposited above wave base in an agitated, well oxygenated environment, and Facies 5 was deposited above wave base in a well agitated, well oxygenated environment. Facies 1 or 2 through 5 represent an ideal regressive sequence.

Comparisons of stratigraphic columns, thin sections, gross lithologic features, and lithofacies succession reveals that the two sections are very similar.

Sea-level fluctuations and consequent changes in depositional environments appear to have been felt equally at both locations. Since age constraints provided by fossil dating are not exact, such close similarity of two sections of Bird Spring located 40 km apart could mean several things. A very gently dipping basin floor might cause an area 40 km farther from shore to experience the same environments as one closer to shore, or the two areas may have been located roughly parallel to the paleo-shoreline at approximately the same depth. Given the poor age constraints, the sections may not be contemporaneous. Similarities in facies types and sequences may be due to facies shifts caused by sea-level fluctuations and not by contemporaneous deposition in uniform seas.

Thesis supervisor: Dr. J.B. Southard

Department Committee: Dr. T.R. Madden

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INTRODUCTION

This study examines the stratigraphy and depositional environment of two sections of the Carboniferous-Permian Bird Spring Formation in Clark County, Nevada. The sections are located in the same thrust sheet and have apparently retained their original relative separation (Burchfiel et al., 1963). Knowledge of the relative positions of the sections permits a revealing comparison of lower Bird Spring stratigraphy and of the depositional environment of the late Paleozoic Bird Spring basin.

Both sections are approximately 180 m thick and form the lowermost part of the Bird Spring Formation. The sections, one in Lee Canyon, the other near Pahrump, lie 40 km apart, separated by the northwest-southeast trending spine of the Spring Mountains. The thrust sheet in which they are located is delimited by the underlying Lee Canyon thrust to the south and the overlying Wheeler Pass thrust to the north (Fig. 3).

Field work was done during the summer of 1983. Sections were measured with steel tape and Brunton compass. Detailed descriptions of each bed were recorded and samples were collected. Five lithofacies representing different environments of deposition were distinguished using the field descriptions and thin-section analysis.

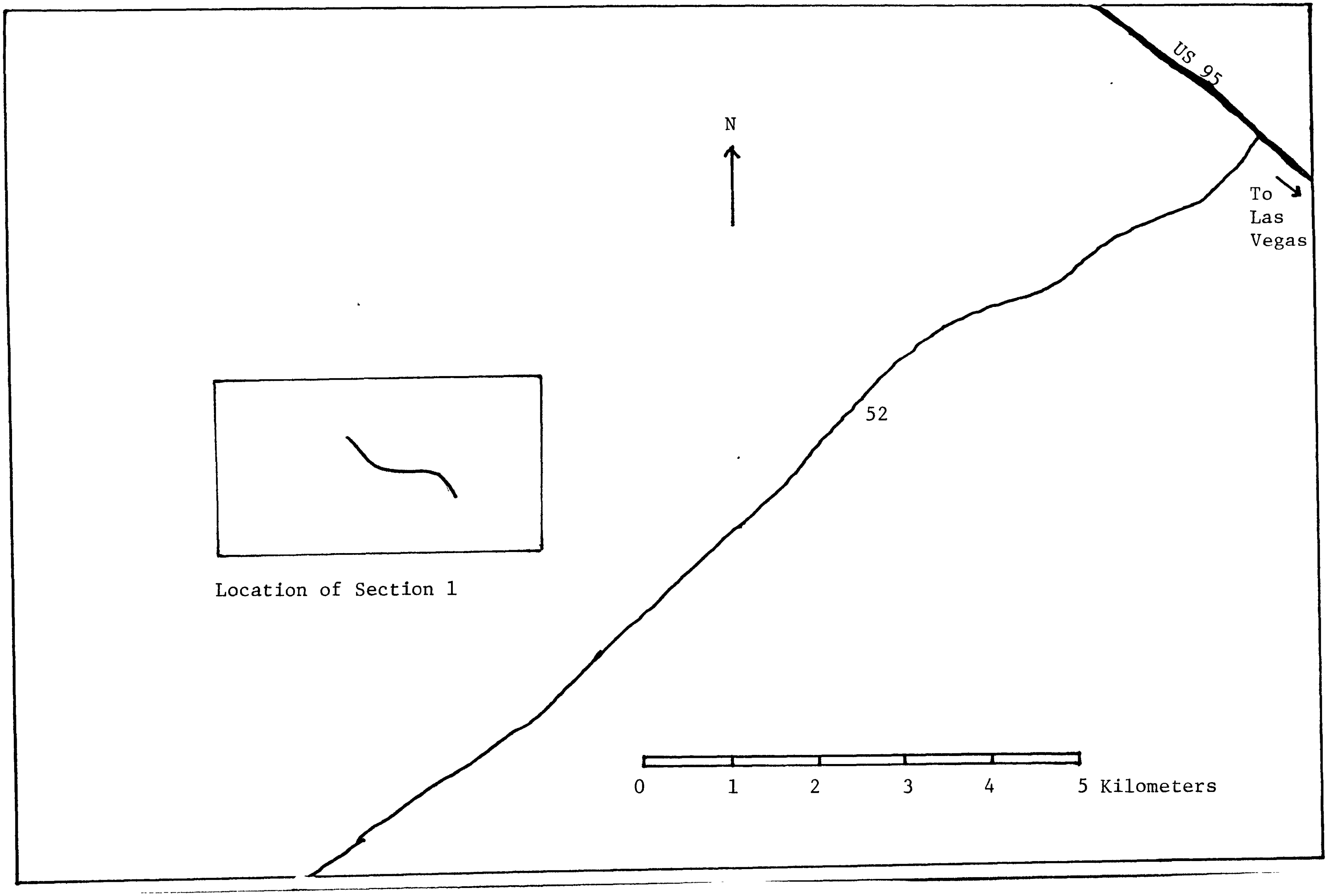


Fig. 1 Lee Canyon Section

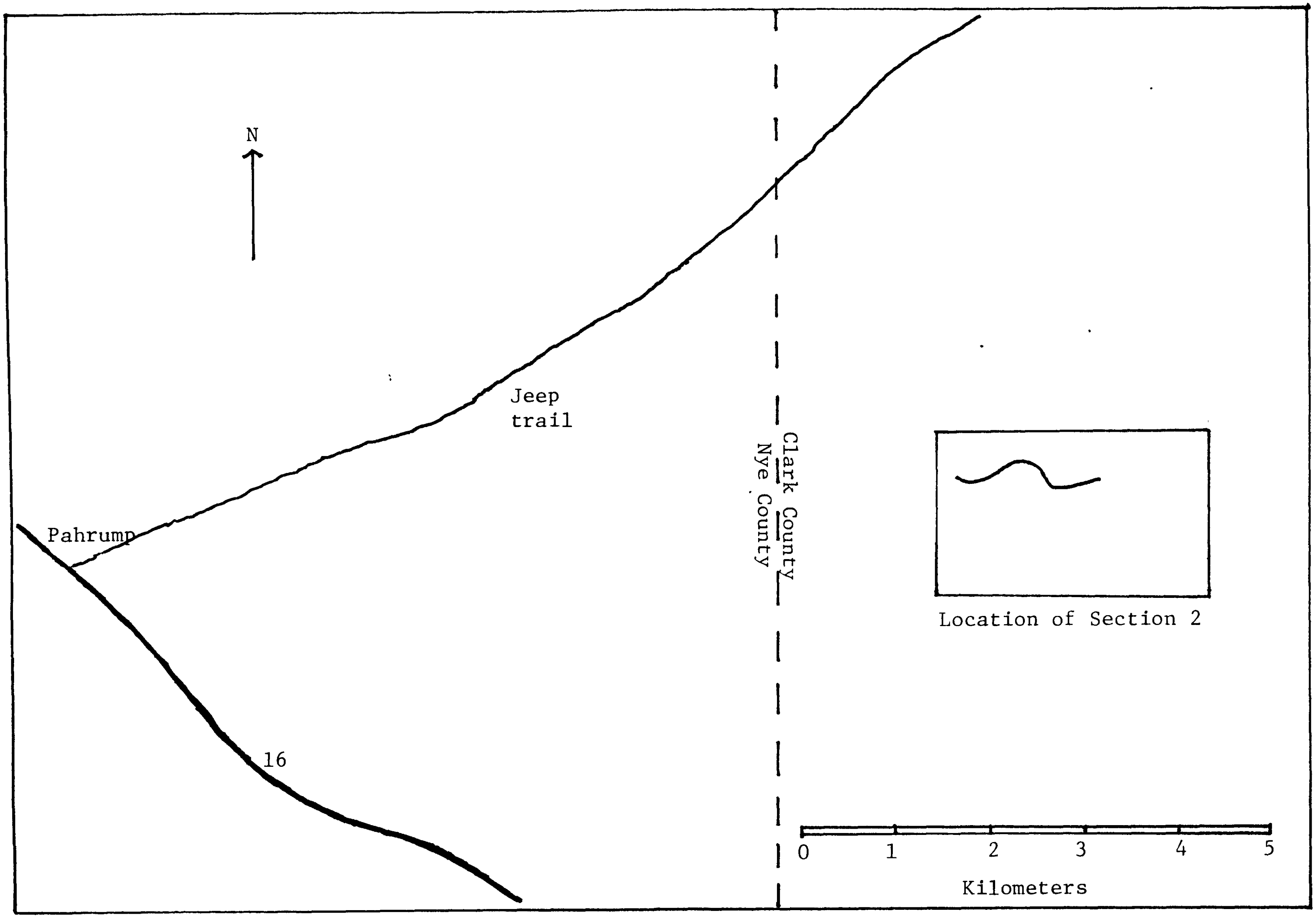


Fig. 2 Pahrump Section

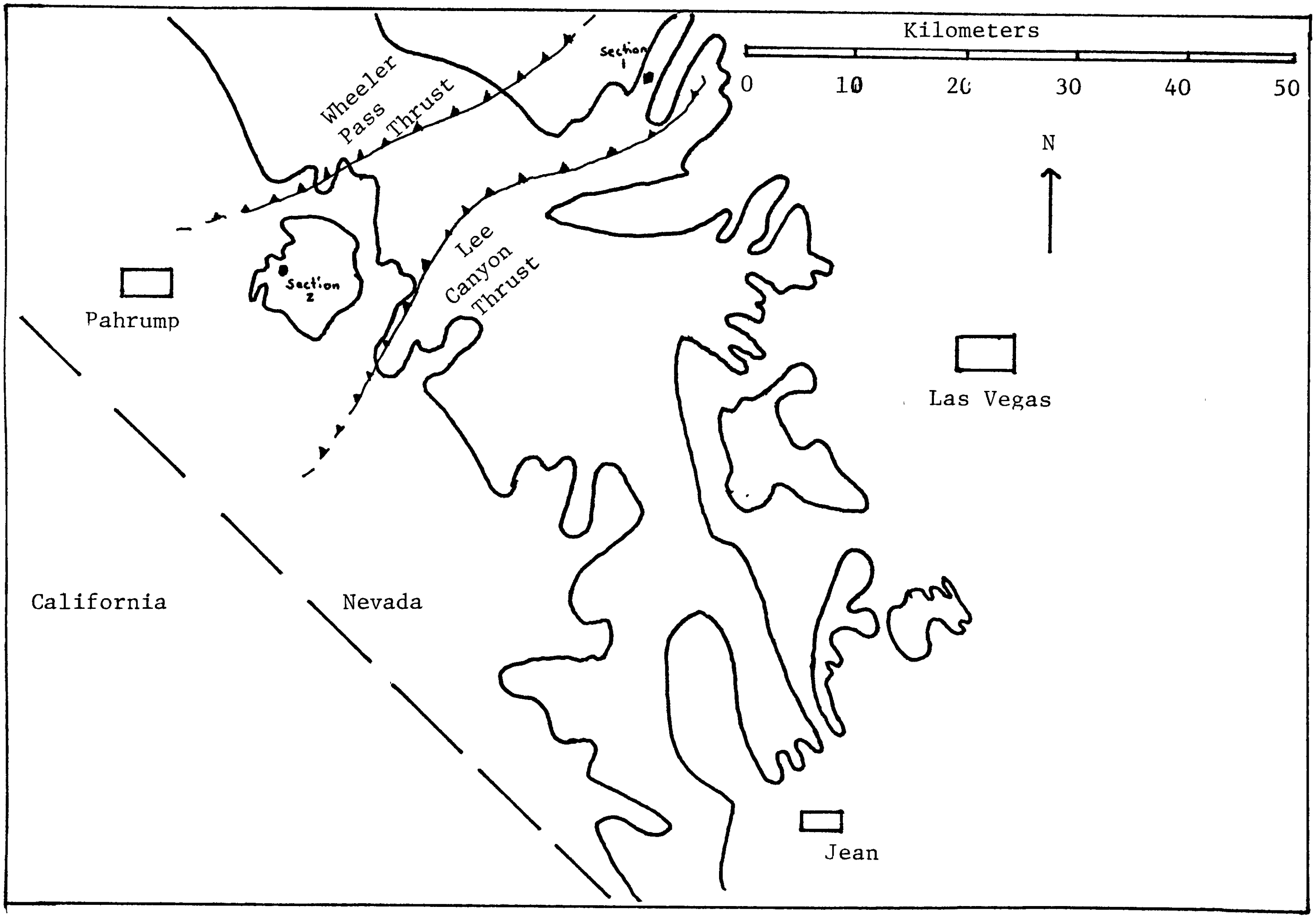


Fig. 3 Spring Mountains

LOCATION

The Spring Mountains are a northwest-southeast trending range lying west of Las Vegas, Nevada. They are composed mainly of upthrusted Paleozoic carbonates. The tallest peak is Mt. Charleston, at 3574 m in height. The higher regions are forested with spruce and piñon pine, and remain pleasantly cool even in the summer. Lower regions are sparsely covered with cactus, mesquite, and dry grasses, and commonly experience temperatures of 45° C at the height of the summmer. Outcrop is generally superb, except in the higher reaches where forests may cover the slopes.

Section 1 lies on the east side of the Spring Mountains, in Lee Canyon (Fig 1). It is located 8 km east of the junction of US 95 and Nevada 52, at long. 115°34'00" W and lat. 36°26'10" N in the NE quarter of the Charleston Peak 15' Quadrangle. The base of Section 1 lies at about 1200 m above sea level.

The Bird Spring Formation in this area has a measured thickness of more than 2100 m. It is broken by only minor faults, but is truncated by erosion at the top. Beds dip gently and uniformly NW 30°.

Section 2 lies on the west side of the Spring Mountains, 11 km east of the town of Pahrump. It is located 7.2 km NE of highway 16, off an unnamed jeep trail shown in Fig. 2. The section is at long. 115°51'30" W, lat. 36°13'00" N in the NE quarter of the Pahrump 15' Quadrangle.

The lower part of the Bird Spring Formation in this area is relatively intact, but upper parts are contorted by many faults and folds. The top of the formation is again missing due to erosion.

PREVIOUS WORK

The Bird Spring Formation was first described and named by Hewett (1931) as part of a survey of the geology and ore deposits of the Goodsprings Quadrangle, Nevada. Hewett assigned the Bird Spring Formation to the Pennsylvanian on the basis of fossils collected from the lower part of the section. The type section, located in the Bird Spring Range, consists of 750 m of limestone, dolostone, calcareous shale, and calcareous sandstone. Chert is fairly common and found mainly as nodules. Fossils including fusulinids, rugose corals, colonial corals, brachiopods, and crinoids are locally abundant. The percentage of terrigenous components varies greatly from bed to bed. The purer limestones and dolostones form ledges, while the less resistant shales and siltstones form slopes. This characteristic weathering pattern of alternating slopes and ledges makes the Bird Spring easily identifiable from a distance.

Longwell and Dunbar (1936) noted that the Bird Spring Formation thickens conspicuously to the northwest. They measured a 1575 m section of the Bird Spring near Indian Springs, 80 km northwest of Las Vegas. On the basis of a fusulinid study, they placed the base of the Bird Spring in the Mississippian. They extended the upper part through the Pennsylvanian into the lower Permian, to lie below the Supai Formation.

Rich (1959) measured a 2100 m section of the Bird Spring in the Spring Mountains, near Lee Canyon, Nevada. A detailed fusulinid study led him to place the lowermost 30 m in the Mississippian, the middle 750 m in the Pennsylvanian, and the uppermost 1350 m in the Permian.

Langenheim et al. (1962) measured 1050 m of Bird Spring Formation in the Arrow Canyon Range, 80 km northeast of Las Vegas, and miles east of the Spring Mountains. Although the upper part of the section is truncated by erosion, the Bird Spring in this area extends through Early Permian Wolfcampian age.

Other authors, including Ledbetter (1970) and Smith (1972), have done work on the Bird Spring and correlative rocks from cratonal and platform sequences found southeast of Las Vegas. The Pennsylvanian-Permian Callville and Pakoon Formations are invariably much thinner and more clastic than the basinal Bird Spring sequence to the north.

PALEOGEOLOGIC SETTING

The Spring Mountains are composed of a thick pile of Paleozoic marine rocks. These rocks, mostly limestones, were deposited on the western margin of the North American craton. In the early Paleozoic a passive North-Atlantic-type plate margin existed in this area (Stewart, 1972). A sequence of marine sediments was deposited in a broad north-trending geosyncline. Near the craton margin, clastic sediments were shed westward in the geosyncline, while farther west in the center of the basin, purer limestones formed (Burchfiel and Davis, 1972).

In Late Devonian-Early Mississippian time the appearance of the Antler orogenic belt to the west of the craton margin marked an end to the passive-margin sequence (Burchfiel and Davis, 1972). The miogeosynclinal portion of the Cordilleran geosyncline in the Eastern Great Basin was transformed into a mildly unstable shelf.

The rocks composing the Spring Mountains were formed near the southeast margin of the area now known as the Great Basin, far enough east of the Antler orogenic belt to have received little if any sediment from the western source (Fig 4).

The eastern Great Basin consisted of numerous depocenters which varied in duration, tectonic behavior, type of sedimentation, and thickness of accumulated sediment (Steele, 1959). The area was not a uniform belt, but rather was differentiated into smaller basin, platform, and positive elements.

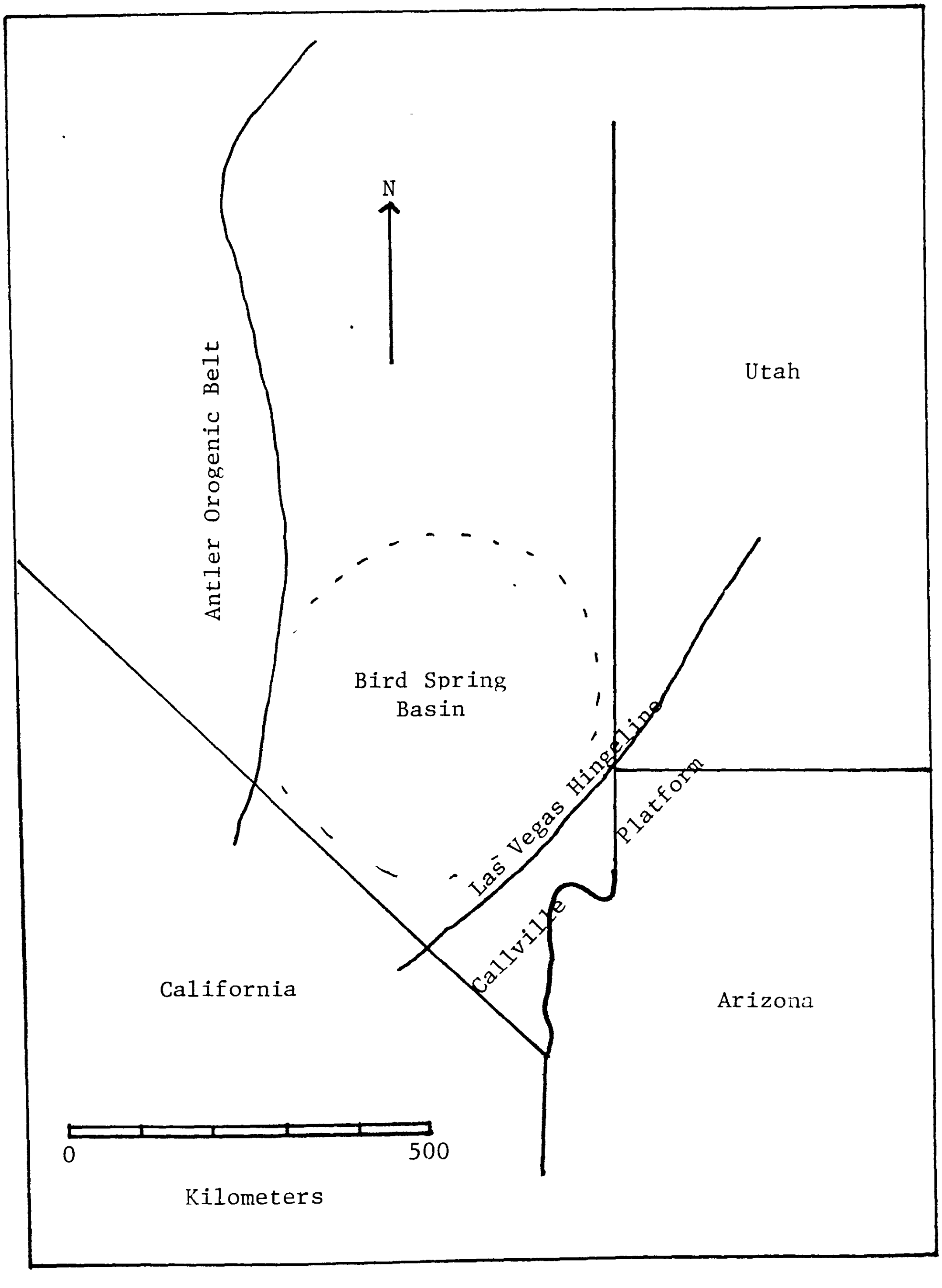


Fig.4 Late Paleozoic Paleogeologic Map (after Bissell, 1962)

These depocenters experienced varying rates of subsidence and uplift throughout late Paleozoic and early Mesozoic time as the tectonic forces to the west affected the Great Basin area (Bissell, 1962). The depocenter in which the Bird Spring Formation was deposited has been called the Bird Spring Basin, the Pioche Basin, the southern sea, and the Inyo-Panamint sea. This author prefers the name "Bird Spring Basin."

The Bird Spring Basin of late Paleozoic time accumulated more than 2100 m of carbonate sediments in its thickest part. It covered roughly 200,000 km^2 with warm shallow marine waters (Steele, 1959). Although sea level fluctuated, resulting in transgressive-regressive sedimentary sequences, the dividing line between platform and basin remained relatively stable. This line, known as the Las Vegas hingeline, runs northeast-southwest approximately through Las Vegas, and separates basin-affinity rocks to the north from platform-affinity rocks to the south (Bissell, 1962).

Bird Spring rocks were formed in basinal facies environments. Their correlative platform rocks are the Callville and Pakoon Formations, deposited on the Callville platform during the Carboniferous and Permian (Smith, 1972). These platform deposits are generally much thinner than correlative basin deposits, and contain much more clastic material.

The type section of the Bird Spring in the Bird Spring Mountains (as defined by Hewett, 1931) lies to the south of the Las Vegas hingeline; these rocks have a more platformal character than the Bird Spring rocks seen in the Spring Mountains. The Bird Spring in the type area contains more clastic components, more cross-stratification, and more primary dolomite, all of which indicate a higher energy, nearer shore environment.

In Early to Medial Permian time a sustained period of uplift caused the retreat of the seas from most of the eastern Great Basin. Several areas were separated from normal marine open-water circulation and became restricted basins with silt, mud, and gypsum deposits. The withdrawal of waters from the Bird Spring Basin ended the deposition of the deep-water Bird Spring Formation and resulted in the deposition of the red and yellow silts and sands of the Supai redbeds. Continued uplift of the Antler orogenic belt in the late Permian finally ended paleozoic sedimentation in the eastern Great Basin (Steele, 1959).

The rocks of the Spring Mountains were all deposited by the end of the Paleozoic Era. The complex tectonic forces affecting the western margin of the North American continent eventually caused east-directed thrusting throughout the southwest (Burchfiel and Davis, 1972). This thrusting, coupled with later episodes of extension, led to the formation of the Basin and Range Province, of which the Spring Mountains are a part.

METHODS OF STUDY

Two stratigraphic columns of the lowermost 180 m of the Bird Spring section were studied, one near Lee Canyon, Clark County, Nevada, the other near Pahrump, Clark County, Nevada. The sections lie approximately 40 km apart. Each bed in each section was described, detailing bedding characteristics, grain size, color, thickness, weathering characteristics, type and amount of visible fossils, type and amount of chert, and type of sedimentary structure present (if any). Both sections were selectively photographed.

Representative samples were collected, several from each of the five main types of lithofacies in each section. Standard thin sections were prepared of each sample. Each thin section was examined for relative amounts of major components, character and amount of different types of bioclastic grains, preservation of grains, types and amounts of non-bioclastic grains, texture, sedimentary structure, types of cement, presence and amount of micrite matrix, and extent of bioturbation.

Five major lithologic units were delineated on the basis of gross lithologic description and thin-section study. The stratigraphic columns were compared and correlations were drawn between them using field descriptions and patterns of lithofacies succession (see fig. 17,18,19).

LITHOFACIES

Five lithofacies were identified in the Morrowan Bird Spring rocks examined in the Bird Spring Mountains.

The bottom 30 m of the Bird Spring Formation, hereafter called the Indian Spring Member, is Chesterian in age, and is markedly different in character from the Pennsylvanian and Permian rocks of the Bird Spring Formation. Indian Spring rocks consist mainly of dense reddish fine-grained finely laminated sandstones cemented with calcite, and of orange-weathering, green-weathering, and purple-weathering coarse-grained limestone with locally abundant fossil remains.

These rocks were deposited in a transitional, nonbasinal environment and are disconformable with the Monte Cristo Formation below. Although Indian Spring rocks appear in both Sections 1 and 2, they are not included as major lithofacies types because they are not basinal in character and were deposited before the formation of the Bird Spring Basin proper. A discussion of Indian Spring rocks is included in the Depositional Environment section of this thesis.

Matrix

Matrix in the Bird Spring rocks is primary or secondary calcite or dolomite. Primary matrix is a very fine-grained carbonate mud (micrite) which often appears to be stained reddish or brownish. In some facies micrite is the only constituent, whereas in others it fills the interstices between larger grains. Secondary cement is formed by precipitation of calcite or dolomite into voids between the grains, or by recrystallization of preexisting micrite. This crystalline cement, or sparite, forms an interlocking mosaic of subhedral calcite or dolomite crystals.

Grains

Some examples of the quieter-water facies are composed entirely of micrite. However, most thin sections examined contained at least some fossil fragments. Uncrushed fossil fragments are fairly common in matrix-supported facies, especially amoing the stronger types of fossils, such as brachiopods and fusulinids. Crushed fragments are seen both scattered through micrite matrix and forming the major constituents of grainstones.

Most facies contain at least some quartz grains. The most quartz-rich facies is basically a micrite-cemented siltstone, with abundant angular silt-size quartz fragments. In most thin sections quartz grains were scattered sparsely and uniformly throughout, but a few examples of each facies (except for the quartz-rich one) contained no quartz at all. The grain size and angularity of the quartz grains suggest an eolian rather than detrital origin.

A few examples each were seen of ooliths, pellets, and lithoclasts. Ooliths were seen in the higher-energy facies and never constituted a large proportion of the grains.

Fecal pellets were occasionally seen in the quieter-water facies, looking like uniform lumps of micrite. Lithoclasts were observed in only one case. These large (2 cm by 1 cm) subangular clasts are composed of micrite, formed when partially consolidated micrite had been torn up and then redeposited, possibly during a storm or other period of atypically strong water movement.

FACIES

Facies 1 is a siltstone or shale, composed of abundant angular to subangular silt-size quartz grains cemented by cryptocrystalline calcareous mud (micrite). Beds are generally poorly resistant to weathering. This facies is often partly or wholly hidden; beds are often weathered to scree-covered slopes, where float may or may not contain examples of the beds beneath. These fine-grained rocks often have pink, orange, tan, or green casts. They contain little or no fossil debris. Chert, locally abundant, is seen in gray or black nodules, 10 cm thick, elongated parallel to bedding.

The few fossils, fine grain size, and lack of cross-lamination indicate a quiet environment, below wave base. Biogenic carbonate production was probably retarded by the presence of abundant silt, which tends to stunt carbonate-producing organisms.

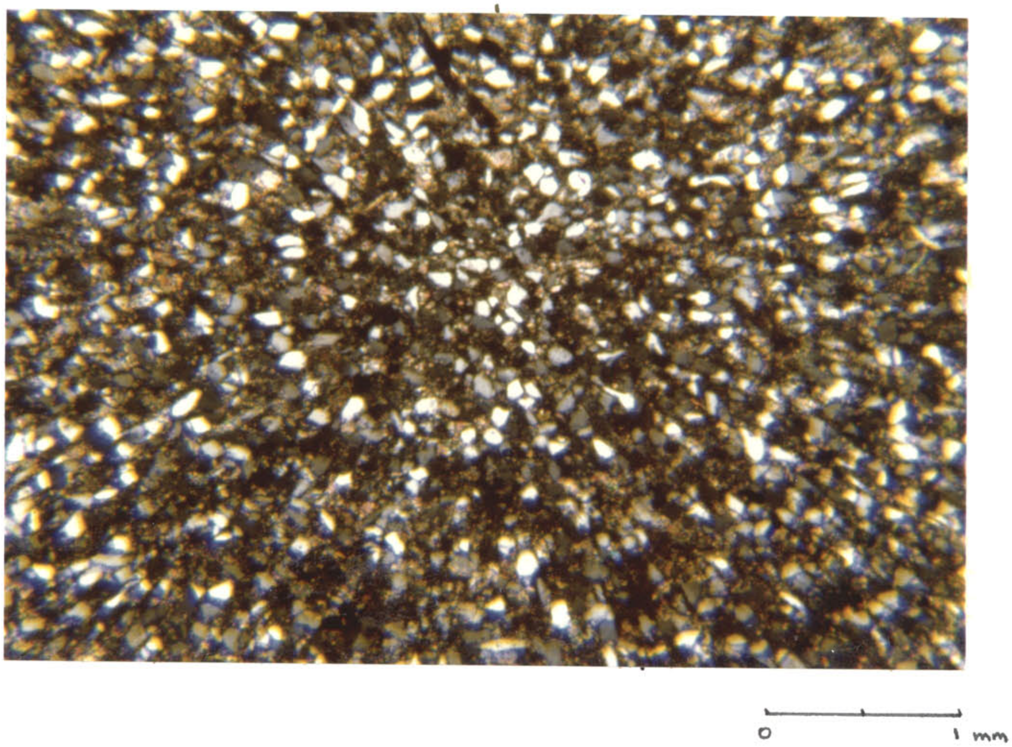


Fig. 5 Facies 1: Siltstone. Lee Canyon. Micrite with well sorted subangular quartz grains. Crossed nicols.

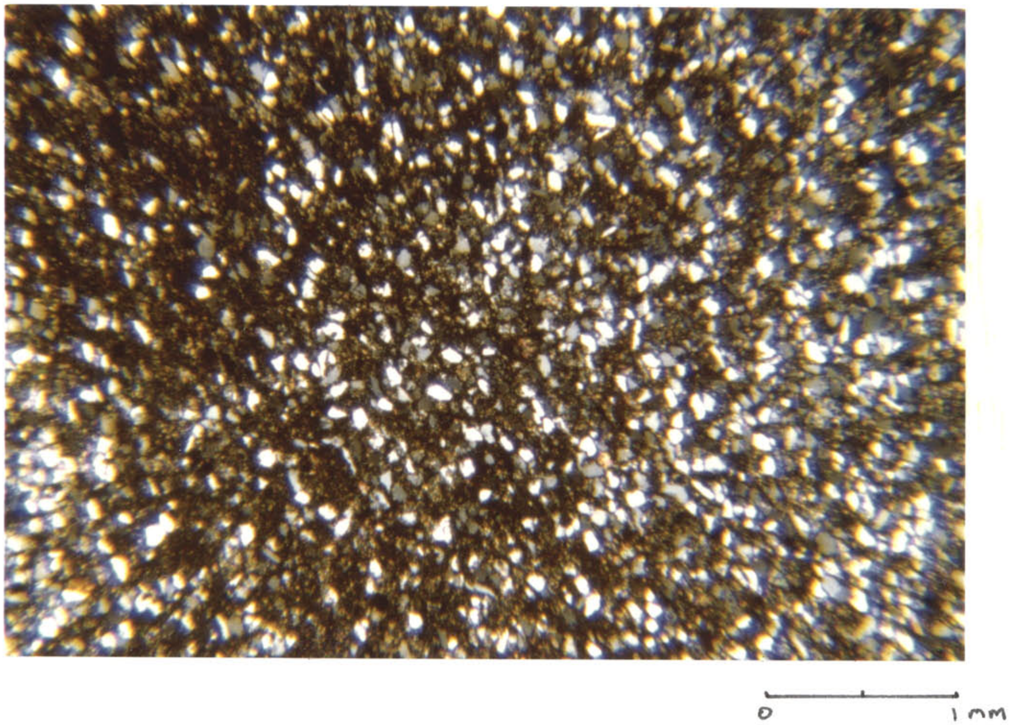


Fig. 6 Facies 1: Siltstone. Pahrump. Micrite with well sorted sub-angular quartz grains. Crossed nicols.

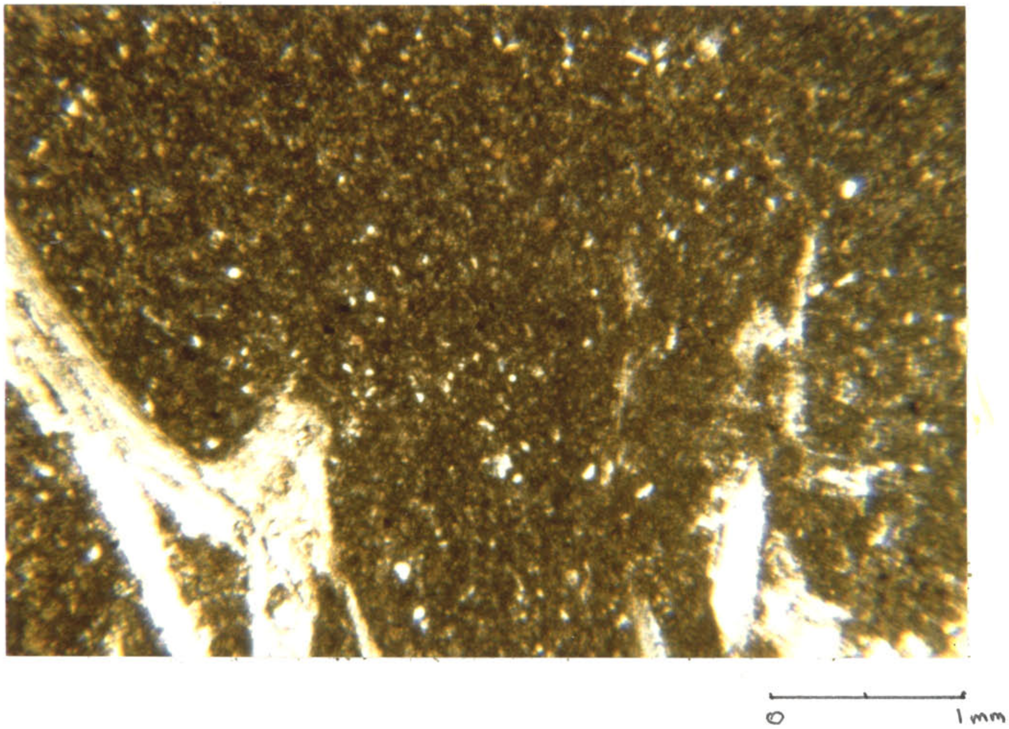


Fig. 7 Facies 2: Micrite. Lee Canyon. Rare quartz grains. Note large uncrushed shell fragment. Crossed nicols.

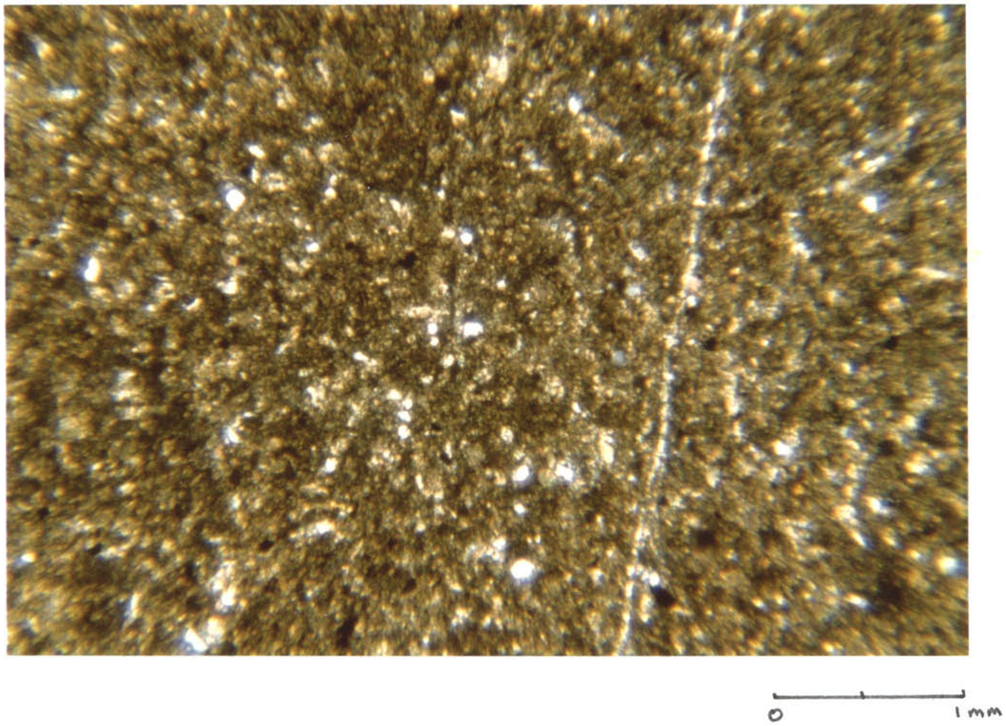


Fig. 8 Facies 2: Micrite. Pahrump. Few quartz grains, no fossil fragments. Crossed nicols.

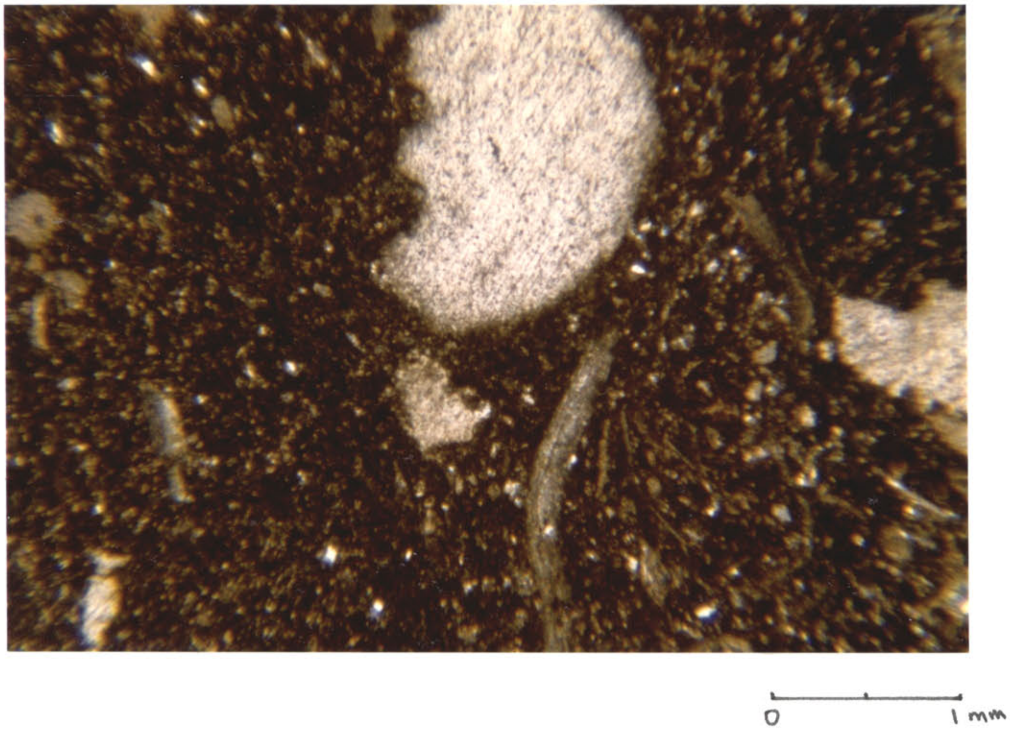


Fig. 9 Facies 3: Matrix-supported biomocrite. Lee Canyon. Reworked fossil fragments (crinoids, echinoids). Crossed nicols.

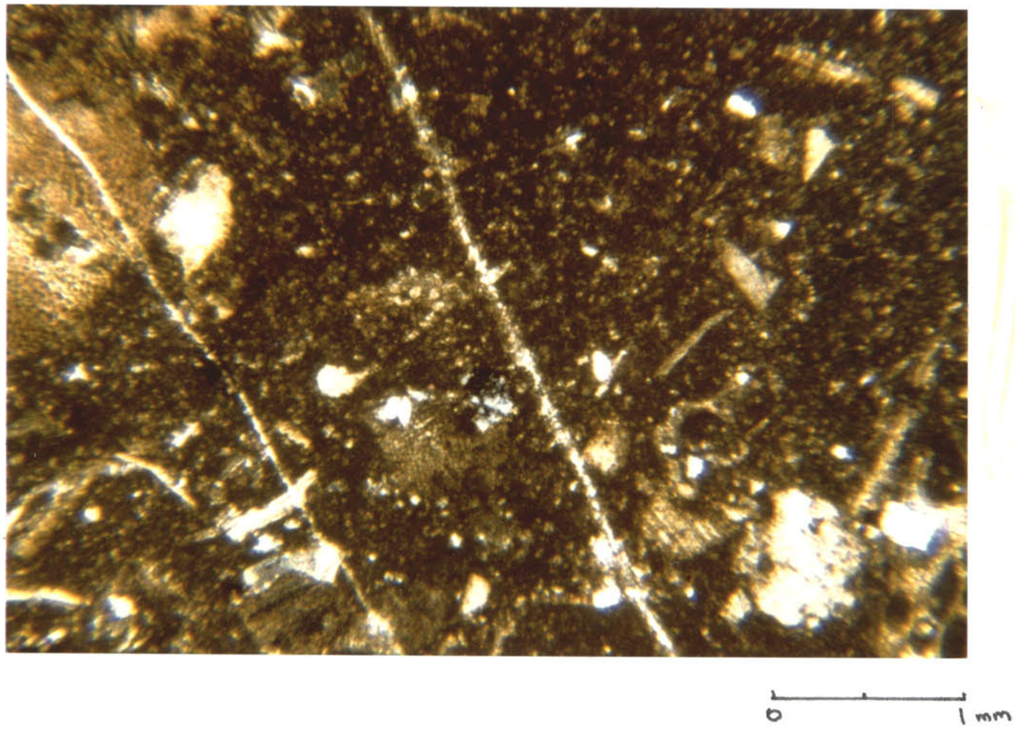


Fig. 10 Facies 3: Matrix-supported biomicrite. Pahrump. Few quartz fragments, reworked fossil fragments. Crossed nicols.

Facies 2 is a micrite, composed almost entirely of cryptocrystalline carbonate mud. Fossil fragments are relatively rare, though some beds do contain large unbroken rugose or colonial corals blanketed by otherwise nearly fossil-free micrite. Fecal pellets are present in small amounts in some beds. Angular quartz fragments are present in small amounts, covering less than 5% of slide area. Chert is locally abundant in nodules parallel to bedding. Pyrite is occasionally present, and freshly broken pieces often emit a sulphurous odor. Euhedral dolomite crystals grow at the expense of micrite but occupy very little area in the slide.

In the field these rocks are unbedded, light-gray to medium-gray fine-grained ledges. Cross-lamination is not present.

The few fossils, lack of cross-lamination, and presence of micrite indicate deposition in a quiet, anoxic environment, below wave base.

Facies 3 is a biomicrite, composed of fossil fragments and fine-grained carbonate mud. It is matrix-supported, and both whole and uncrushed fossil fragments are present. Angular silt-size quartz fragments make up less than 5% of constituents. Fossil fragments make up between 10% and 30% of the area on a slide. Dolomite rhombs growing at the expense of micrite are present but not as common as in Facies 2. Fecal pellets are present in small amounts.

In the field these rocks are fine-grained to medium-grained and medium-gray in color. Fossil fragments may be visible on weathered surfaces. Beds are generally massive and form impressive cliffs.

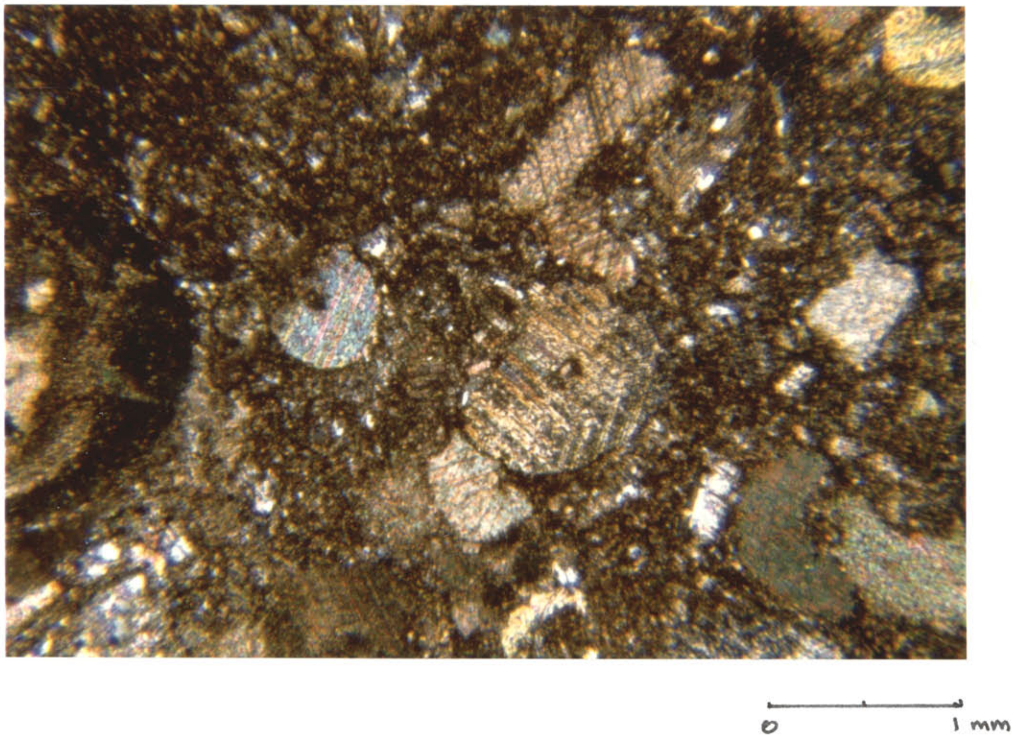


Fig. 11 Facies 4: Grain-supported biomicrite. Lee Canyon. Reworked fossils. Crossed nicols.

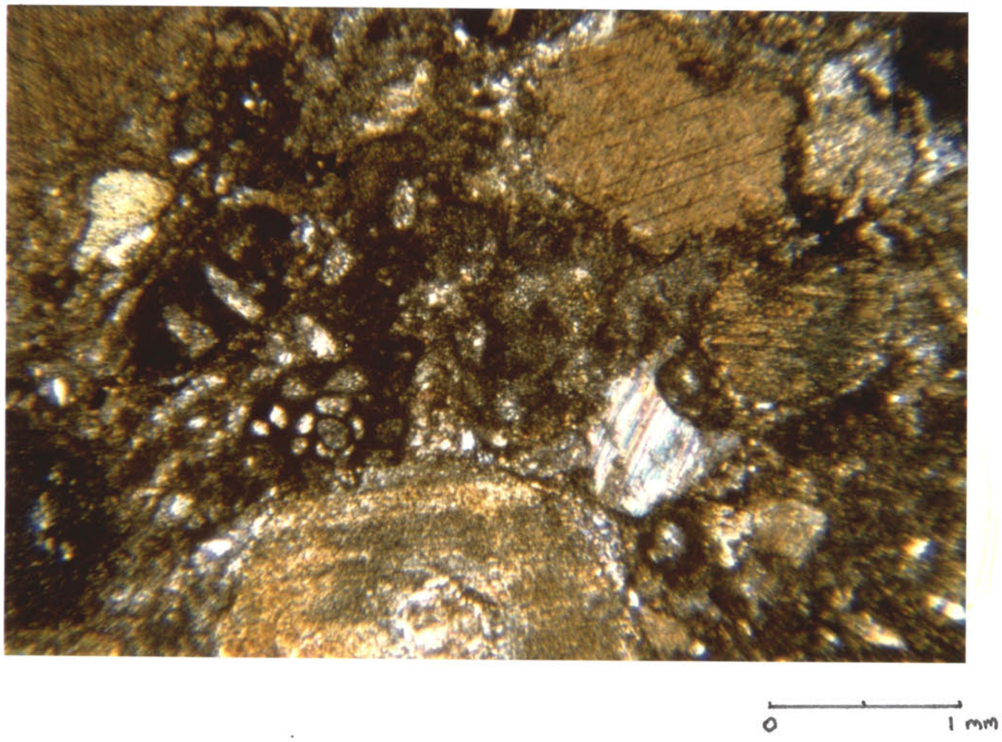


Fig. 12 Facies 4: Grain-supported biomicrite. Pahrump. Reworked fossils (crinoids and fusulinids). Crossed nicols.

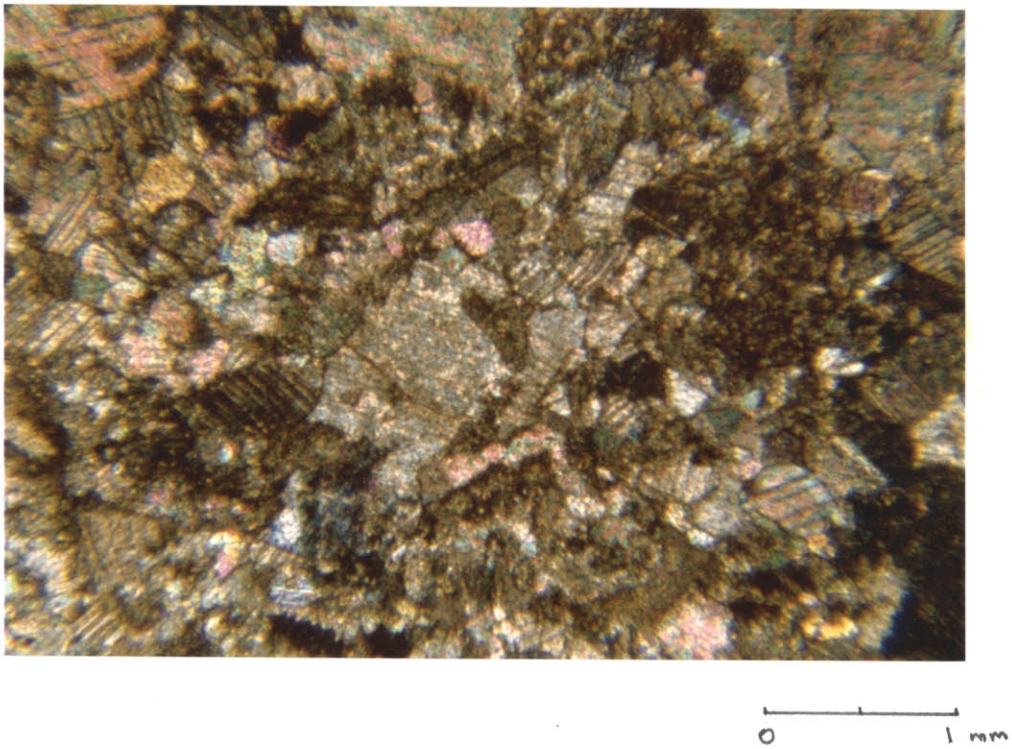


Fig. 13 Facies 5: Biosparite. Lee Canyon.
Crossed nicols.

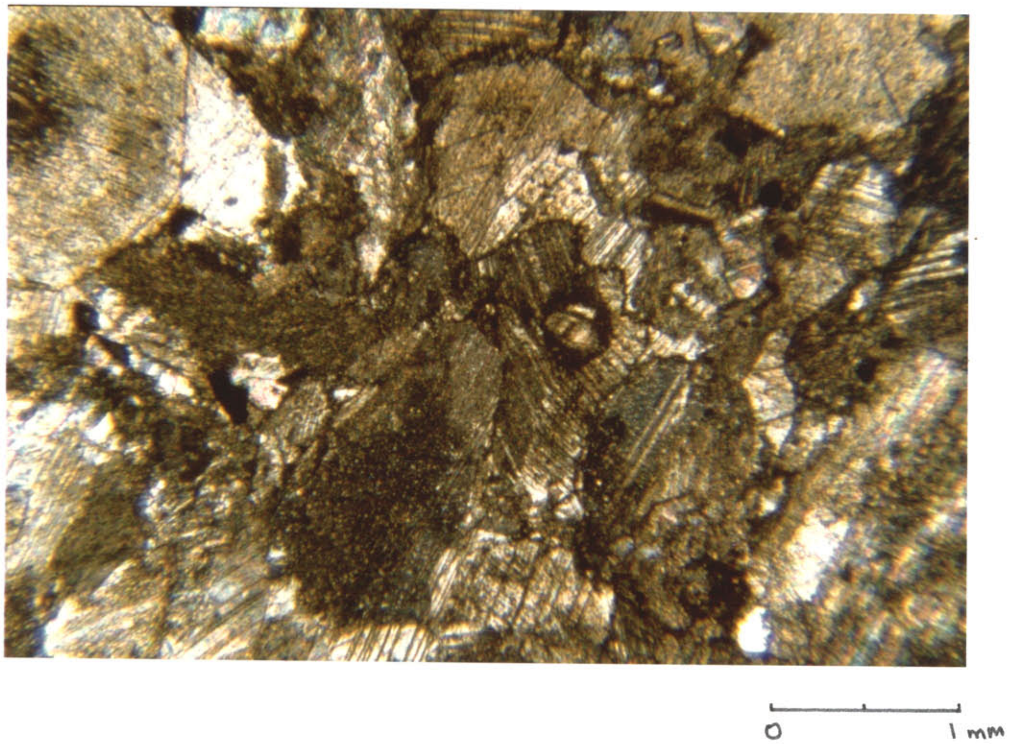


Fig. 14 Facies 5: Biosparite. Pahrump.
Crossed nicols.

Gray and black chert pods and nodules are locally abundant. Cross-lamination is absent.

The presence of fairly abundant fossil fragments, often somewhat reworked, indicates deposition in a moderately active environment, in the photic zone, probably close to wave base.

Facies 4 is a grain-supported biomicrite, composed of both whole and crushed fossils with a scant micrite matrix. Fossils include crinoids, brachiopods, trilobites, and gastropods. Quartz fragments are rare.

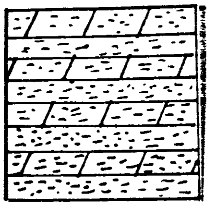
Field appearence is massive, medium-grained to coarse-grained medium-gray limestone with fossils easily visible on weathered surfaces. Chert is present locally. Large-scale cross-lamination is present in some beds, with beds 3 to 5 cm thick and up to several meters in lateral extent.

The well-washed and reworked fossils and the presence of cross-lamination indicate deposition in an energetic, well oxygenated environment, above wave base.

Facies 5 is a biosparite, composed of fossil fragments and sparry cement. Both whole and crushed fossils are bound by an equigranular mosaic of crystalline calcite. Sparry cement was probably formed by recrystallization of a preexisting micrite matrix. Quartz grains are absent in this facies.

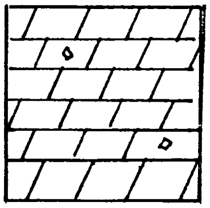
Field appearence is a very massive unbedded medium-gray, medium-grained to coarse-grained limestone whose fresh surfaces sparkle in the sun.

The secondary recrystallization of this facies has obliterated the original grain/matrix composition. However,



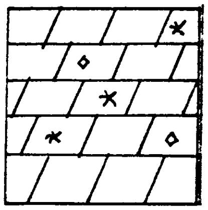
Facies 1

Siltstone or shale: angular silt-size quartz grains in micrite. Fossils rare. Chert locally abundant. Below wave base.



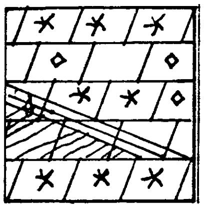
Facies 2

Micrite: cryptocrystalline carbonate mud. Fossils rare. Little or no quartz. Below wave base.



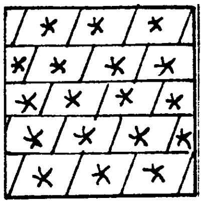
Facies 3

Matrix supported-biomicrite: fossils are somewhat reworked. Near wave base.



Facies 4

Grain-supported biomicrite: fossils are reworked. Ooliths and cross-lamination sometimes present. Above wave base.



Facies 5

Biosparite: recrystallized fossil fragments and micrite. Above wave base.

Fig. 15 Lithofacies

the presence of fossils indicates deposition in a well oxygenated environment. Reworked fossils suggest an agitated environment, above wave base.

The five lithofacies described above are elements of a sedimentary cycle deposited in response to sea-level fluctuation. An ideal regressive sequence would progress from the quieter-water, deeper-water facies (Facies 1 and 2) through increasingly shallower water and more agitated conditions (Facies 3) to the most agitated environments (Facies 4 and 5). The ideal transgressive sequence would contain the same elements but in opposite order.

Although the Bird Spring Basin experienced many transgressive-regressive cycles, the sequence of facies deposited is often not the ideal "Facies 1 through Facies 5 through Facies 1." Incomplete cycles are common; when sea level did not transgress or recede as far as it had in the past, not all members of the cycle were deposited. Another reason for incomplete cycles is that not all elements of each cycle have been preserved. This is especially true for regressive sequences, where the shallower, more agitated conditions following quieter, deeper-water conditions tended to obliterate previously deposited unconsolidated finer-grained sediment.

Analysis of the beds that are preserved will reveal the succession of facies in an area. Since facies are dependent on depositional environment, water depth can also be inferred from bed analysis.

DEPOSITIONAL ENVIRONMENT

Before the Bird Spring Basin reached its full extent at the end of Chesterian time, a smaller, shallower sea covered parts of the same area. The Indian Spring Member of the Bird Spring Formation was deposited at this time. The Indian Spring Member contains a large proportion of terrigenous clastic constituents. It was deposited in a shallow, energetic, above-wave-base environment. Minor sea-level fluctuations occurred during the deposition of the Indian Spring Member, producing alternating beds of fine-grained cross-laminated sandstone and coarse-grained biosparite.

At the end of the Mississippian Period, a large-scale marine transgression, which was to last essentially to the end of the Paleozoic, ended deposition of the shallow-water Indian Spring Member and began deposition of the deeper-water Bird Spring Formation.

Although the Bird Spring basin deepened in the Pennsylvanian Period, water depth probably never exceeded 100 m; Bird Spring lithofacies are characteristic of shallow marine seas.

The Bird Spring Formation was deposited in a broad, relatively shallow, warm marine basin. The Bird Spring Basin provided nearly ideal conditions for the deposition of carbonate sediments: warm temperatures, light, silt-free water, and slightly agitated conditions.

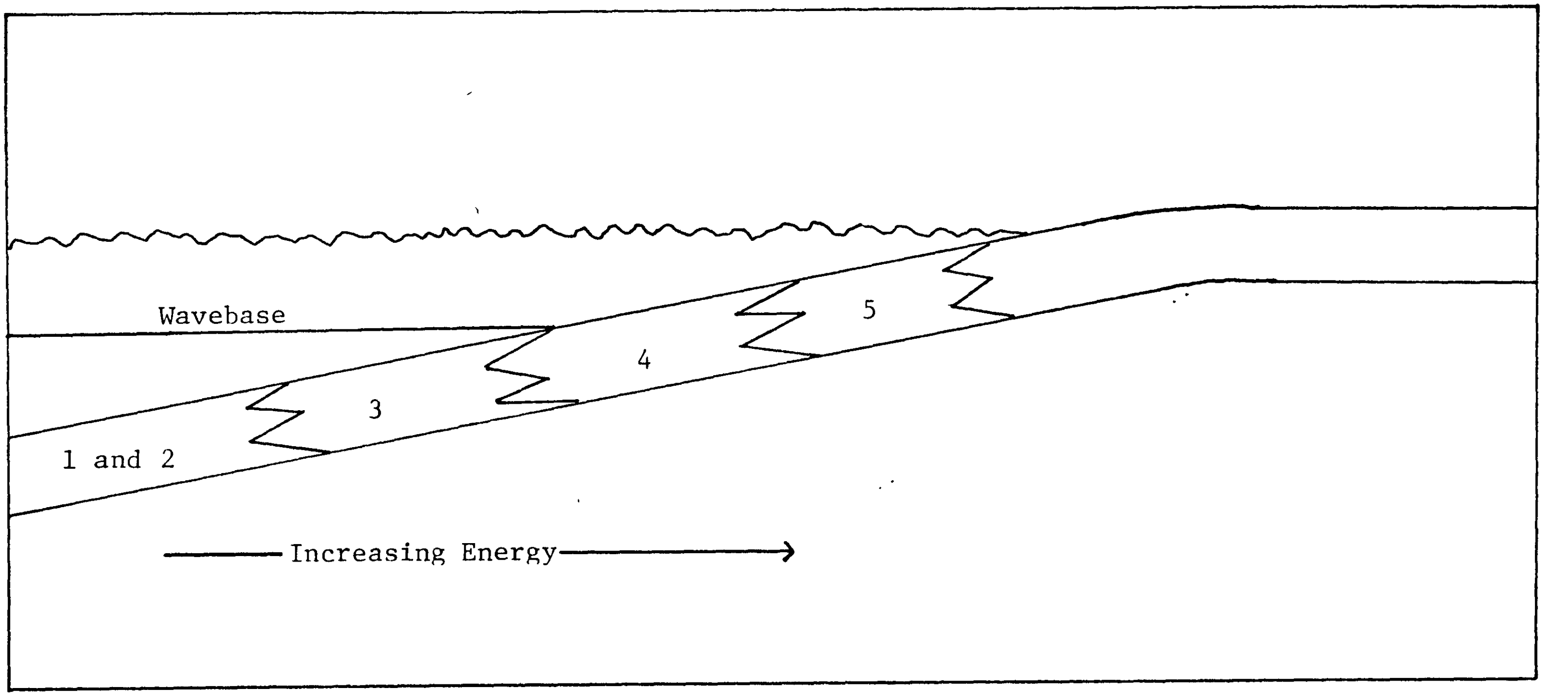


Fig. 16 Horizontal Interpretation of Facies Type

These favorable conditions allowed the deposition of thousands of meters of carbonate in the slowly subsiding basin. Although carbonate deposition continued throughout the late Paleozoic, environmental conditions were not entirely static, for Bird Spring rocks are by no means uniform from bed to bed. They vary in color, grain size, percent of clastic constituents, shape of grains, type and amount of biogenic debris, type of sedimentary structures and many other factors. The five lithofacies described above were deposited in the slightly differing environments that are produced by fluctuations in sea level.

Transgression and regression of the seas, induced by variable subsidence rate, climatologicical variation, or some other factor, caused the deposition of cyclic sedimentary sequences. As water depth in the basin fluctuated, the environment in any given location changed as well.

Sea level could not have fluctuated between great extremes in the area examined in this study; while depositional environments varied with time and sea level, all facies are characteristic of restricted basins. With the exception of the Indian Spring Member, the Bird Spring Formation contains few terrigenous clastics and little cross-stratification.

SYNTHESIS AND DISCUSSION

The thick column of Bird Spring rocks preserves a record of cyclic facies changes in response to changes in sea level; this record is necessarily vertical and time-dependent. The study of succeeding beds in one vertical stratigraphic column is useful in determining which environments occurred when, but tells the worker little of the horizontal variations in facies that occur at the same time in a basin.

The Bird Spring Basin covered approximately 200,000 km^2 in Carboniferous time. Study of a great many stratigraphic sections is necessary to discover the lateral extent of depositional environments in the basin. Unfortunately, Mesozoic and Tertiary tectonism and the resulting deformation have complicated the problem. The Bird Spring Basin has been greatly shortened by east-directed low-angle thrust faults, and is cut in many places by normal faults. Those areas that were not uplifted into mountain ranges are now covered by alluvium. Reconstruction of the original basin has proved difficult; stratigraphic sections measured in the same mountain range within a few kilometers of each other may lie on different thrust sheets and thus retain nothing of their original separation.

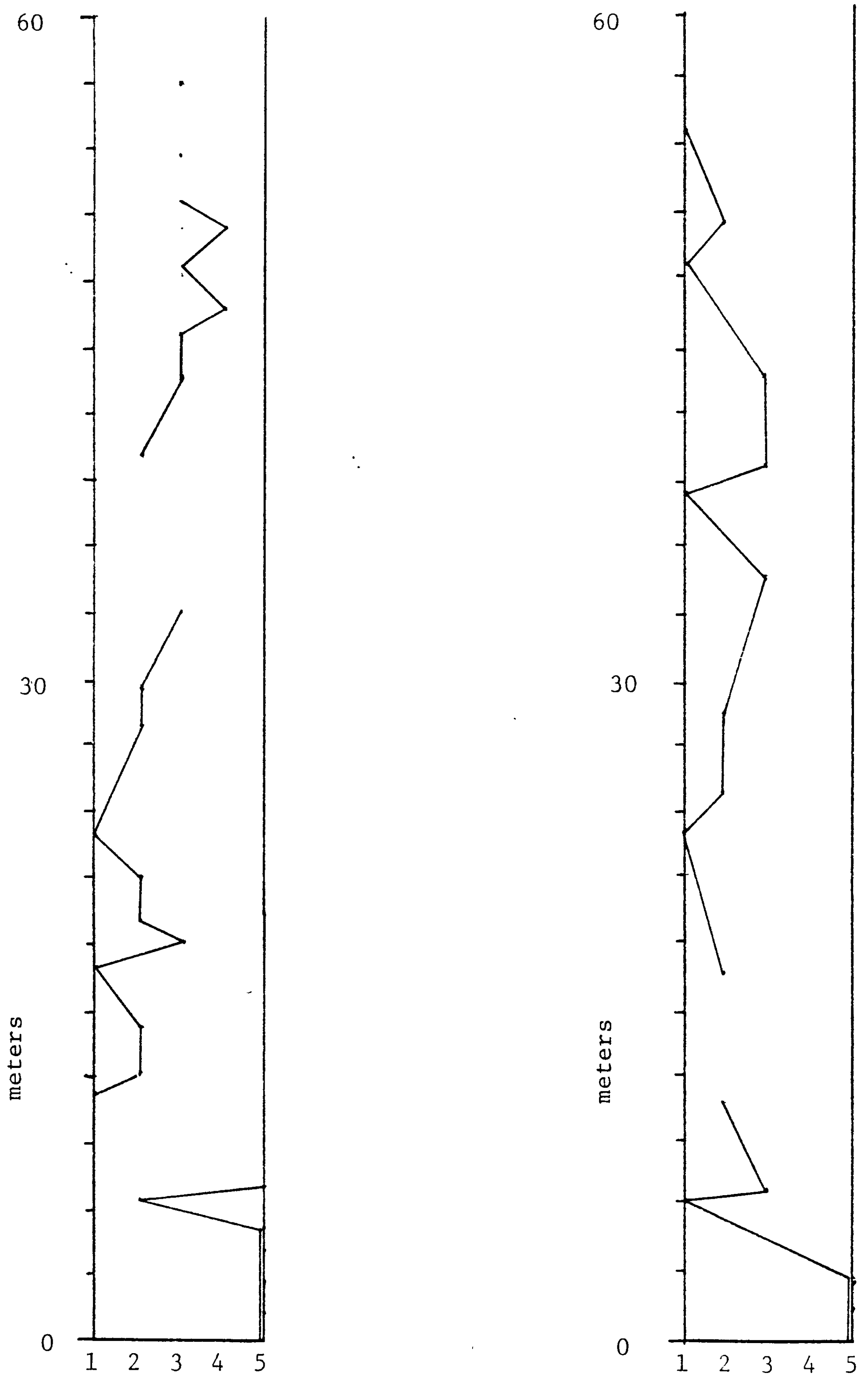
The Spring Mountains are cut by several major thrust faults as well as numerous minor faults and folds, but

Sections 1 and 2 lie in the same thrust sheet (Burchfiel et al.) Deformation within the thrust sheet delimited by the Lee Canyon Thrust to the north and the Wheeler Pass Thrust to the south appears to be minimal. Although the original position of this thrust sheet is poorly constrained, Sections 1 and 2 seem to have retained their original relative separation of about 40 km.

Comparison of Sections 1 and 2 reveals many similarities. The overall character of the beds in both sections is the same. They are composed of similar rocks: the same five lithofacies are found in both areas. The percentage of each lithofacies is similar, and the faunas appear to be nearly identical. Chert is abundant in both sections.

Study of the stratigraphic columns reveals more similarities. The lowermost part of the Bird Spring Formation, the Indian Springs Member, is present in both locations. Approximately 30 m thick, it is composed of the same two lithologic types--dense reddish fine-grained cross-laminated sandstone, and very coarse-grained orange-tinted, green-tinted or purple-tinted biosparite. Poor preservation of the Indian Spring Member in the Pahrump area made a bed-by-bed comparison with the Lee Canyon area impossible, but the overall character of this member is the same.

The 60 m of Bird Spring directly above the Indian Spring Member alternate between ledges and debris-covered slopes. Many of the ledges in both sections contain uncrushed recrystallized calcite or silica-replaced brachiopods. These fossils tend to weather out of the bed, which makes them easy to see.



Pahrump

Lee Canyon

Fig. 17 Lithofacies Succession

Lithofacies types are represented by horizontal scale. Vertical scale represents distance above top of Indian Spring Member.

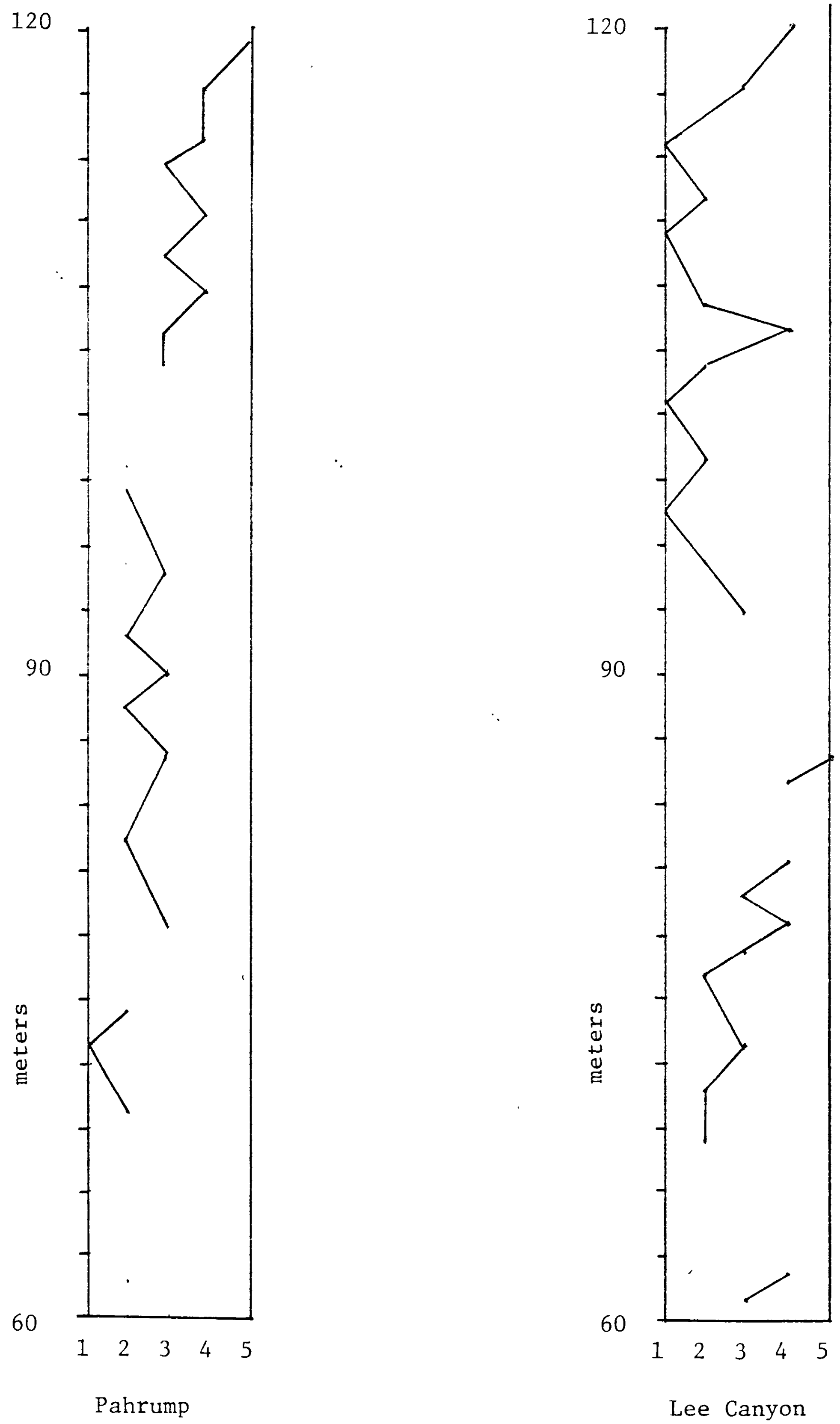
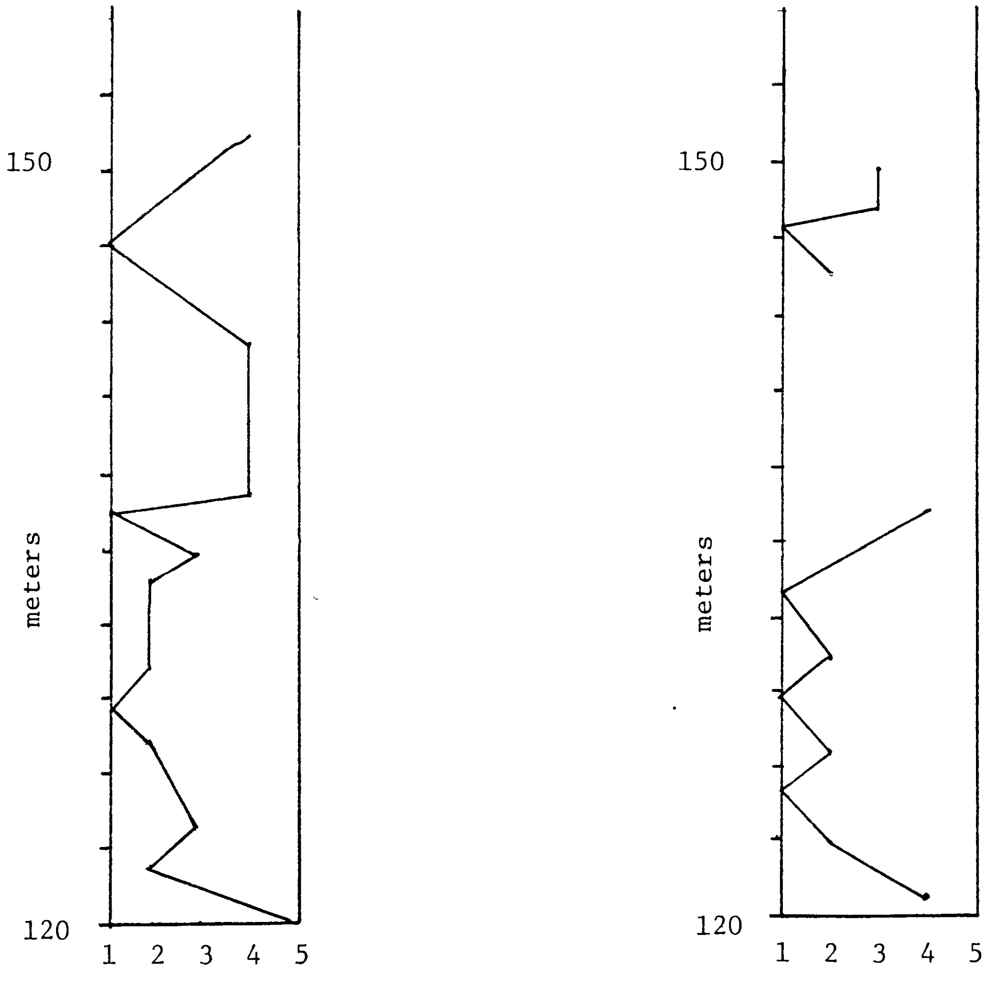


Fig. 18 Lithofacies Succession



Pahrump

Lee Canyon

Fig. 19 Lithofacies Succession

Chert nodules and layers are common in both sections.

Between 90 and 125 m from the base, most of the beds are resistant to weathering and form massive cliffs. Layers of chert nodules are very common, ranging from 10 to 15 cm in thickness and lying from 0.3 to 1 m apart. Very few megascopic fossils are present in this part of the section.

In the interval between 125 and 180 m, beds in the Bird Spring again alternate between slope-formers and ledge-formers. Chert is common in both sections. Some beds in Section 1 contain brachiopods, and both sections contain some rugose corals.

The first fusulinids in Section 1 were found 120 m from the bottom. In Section 2, the first fusulinids were found 165 m from the bottom. Both were identified as *Millerella marblensis*.

Study of lithofacies succession (figs. 17,18,19) provides another basis for comparison. Curves are extrapolated across covered intervals unless the covered interval exceeds 3 m. Poor preservation of the Indian Spring Member in Section 2 made comparative analysis of the Indian Spring Member impossible; comparison of lithofacies starts at the top of the Indian Spring Member.

Both sections have initially high energies of deposition. Facies changes in the interval from 0 to 60 m are roughly similar, although bed-to-bed correlations can be drawn only in the lowermost 12 m. In the interval 60 to 115 m there appears to be little similarity between the two sections. Between 115 and 150 m, lithofacies successions again appear to be very similar.

Although few bed-to-bed correlations can be drawn between the two Bird Spring sections, they are very similar in overall character and appearence. The only real difference between them is the placement of the Facies 1 siltstone beds. Both sections contain approximately the same number of siltstone beds, but they do not lie at equivalent stratigraphic levels.

Facies 1 siltstones are composed of more than 50% silt-size quartz fragments. The fragments are angular to subangular and extremely well sorted. They are distributed uniformly throughout the bed and do not form layers. The size and sorting of these particles suggests that they were picked up by currents and carried in suspension, and deposited only when they reached the quiet waters of the inner basin.

Eolian transportation is possible, but winds strong enough and steady enough to carry large amounts of silt for at least 160 km would probably not create such localized deposits. If eolian transport was indeeed the mechanism for silt deposition, locations 40 km apart would likely receive silt at the same time.

Detrital silt carried in suspension from a river or submarine fan deposit would tend to form relatively localized deposits such as those seen in Sections 1 and 2.

CONCLUSIONS

Despite its great size, the Bird Spring Basin was probably never more than 100 meters deep. The shallow dip of the basin floor makes it difficult to estimate the distance of Sections 1 and 2 from the paleo-shoreline, but it probably lay about 160 km to the southeast (Ledbetter, 1970).

The gentle dip of the basin floor made the basin very responsive to sea level changes. A small drop in water level caused a relatively large regression and affected the depositional environment of a large area.

Similarity of Bird Spring sections located 40 km apart could be due to several things. A very gently dipping basin floor might cause an area 40 km farther from shore to experience the same environment as one closer to shore, or the the two sections may have been located roughly parallel to the paleo-shoreline at approximately the same depth. These explanations assume that the sections were deposited contemporaneously, but the age constraints provided by fossil dating do not rule out the possibility that the similar sections were deposited non-contemporaneously in large-scale facies shifts caused by sea-level fluctuation.

Differences in silt deposition are due to the tendency of detrital silts to form relatively localized deposits.

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APPENDIX: DETAILED DESCRIPTION OF SECTIONS

Lee Canyon Section

Bed #	Thickness in meters	Cumulative thickness in meters	Description
	5.0	5.0	Massive coarse-grained medium-gray-weathering limestone with many crushed fossil fragments. Chertified brachiopods in some layers. One 2.5 cm layer of rusty brown chert. Ledgy.
	1.0	6.0	Covered interval
	0.3	6.3	Fine-grained reddish siltstone with some whole fossils.
	0.5	6.8	Dense medium-grained, medium-gray limestone. Few large fossil fragments.
	5.0	11.8	Covered interval
	1.0	12.8	Fine-grained light-gray to medium-gray Limestone with few large whole fossils and scattered fragments.
	5.0	17.8	Covered interval
	1.5	19.3	Dense fine-grained medium-gray limestone. Some chertified brachiopods. Chert nodules, 15 by 30 cm. Dense 8 cm black chert layer at top.
	3.5	22.8	Covered interval
	2.7	25.5	Fine-grained medium-gray silty limestone. Abundant chert pods in layers 8 cm thick. A few brachiopods present.
	0.5	26.0	Medium-grained medium-gray limestone with one bed of brown chert nodules, 30 cm in diameter.
	2.7	28.7	Covered interval
	2.0	30.7	Medium-grained medium-gray limestone with layers of black chert nodules.

Bed #	Thickness in meters	Cumulative thickness in meters	Description
	2.7	33.4	Covered interval
	2.5	35.9	Fine-grained and medium-grained light-gray to medium-gray limestone. Some layers are coarser grained with visible fossil fragments. Brownish chert nodules present. Ledgy.
	3.5	39.4	Fine-grained to medium-grained light-gray, peach-weathering siltstone.
	1.5	40.9	Medium-grained medium-gray limestone.
	3.0	43.9	Covered interval
	1.0	44.9	Medium-grained medium-gray limestone with abundant gray and black chert nodules and beds.
	2.1	47.0	Covered interval
	2.4	49.4	Fine-grained light-gray silty limestone. Weathers tan.
	2.1	51.5	Medium-grained medium gray limestone with rust-brown chert nodules and beds. Some chert-replaced brachiopods.
	2.7	54.2	Covered interval
ABS 7	1.0	55.2	Fine-grained pinkish siltstone with one layer of dense black chert, 8 cm thick.
	5.4	60.6	Covered interval
	3.0	63.6	Medium-grained medium-gray limestone. Coarsens near top Some chert-replaced brachiopods,some dark-gray chert nodules.
	5.0	68.6	Covered interval

Bed #	Thickness in meters	Cumulative thickness in meters	Description
ABS 8	6.5	75.1	Bottom 2 m is fine-grained to medium-grained crystalline limestone with chert layers, 8 to 20 cm thick, and approx. 0.5 m apart. Middle 3 m is massive featureless fine-grained medium-gray limestone. Top 1.5 m is composed of medium-grained medium-gray limestone containing cross-stratified 1 cm thick chert layers. Cliff former.
	2.1	77.2	Covered interval
	3.0	80.2	Fine-grained medium-gray to dark-gray limestone. Some beds of densely packed crinoid fragments. Chert nodules in beds 8 to 30 cm thick. Cliff former.
	3.0	83.2	Medium-grained medium-gray to light-gray limestone. Some contain 1 cm diameter crinoid fragments. Chert nodules and beds present. Cliff former.
	2.5	85.7	Covered interval
ABS 9	1.5	87.2	Medium-grained medium-gray limestone, some layers of coarse fossil hash. Some chert beds and chert-replaced rugose coral present. Cliff former.
ABS 10	3.0	90.2	Fine-grained to medium-grained medium-gray limestone. Chert-replaced rugose coral present in two .5 m thick beds. Forms slopes and ledges.
	4.0	94.2	Fine-grained medium-gray limestone. Weathers into layers 20 to 45 cm thick. Some orange chert layers present. Rough and craggy at top. Forms cliffs and ledges.

Bed #	Thickness in meters	Cumulative Thickness in meters	Description
	10.0	104.2	Fine-grained to medium-grained light-gray silty limestone. Some beds contain coarse crinoid and brachiopod fragments. Black chert nodules are abundant. Forms slopes and ledges.
	3.0	107.2	Covered interval
	5.5	112.7	Fine-grained to medium-grained light-gray to medium-gray silty limestone with abundant black chert nodules in beds 15 cm apart. Weathers shaley. Forms slopes and ledges.
	2.0	114.7	Medium-grained medium-gray limestone. Concentrically layered chert nodules 8 cm in diam. present in lower 1 m. Top 1 m contains dense orange chert layers. Forms a ledge.
	2.0	116.7	Covered interval
ABS 11	2.0	118.7	Coarse-grained crystalline medium-gray to light-gray massive limestone. Several chert beds, 15 cm thick. Forms a ledge.
	12.5	131.2	Fine-grained to medium-grained medium-gray to light-gray silty limestone with abundant chert nodules. Some beds of coarse fossil fragments. Forms slopes and ledges.
ABS 12	2.4	133.6	Coarse-grained medium-gray limestone. Thin chert beds accentuate large-scale cross-stratification. Forms a ledge.
	7.5	141.1	Covered interval
	3.5	144.6	Fine-grained to medium-grained light-gray silty limestone with orange-brown chert beds.

Bed #	Thickness in meters	Cumulative thickness in meters	Description
	1.0	145.6	Medium-grained medium-gray limestone. Massive. Little chert, few fossils. Forms a ledge.
	0.5	146.1	Covered interval
	0.5	146.6	Medium-grained to coarse-grained medium-gray limestone. Massive. Ledge former.
	2.5	149.1	Covered interval

Pahrump Section

Bed #	Thickness in meters	Cumulative thickness in meters	Description
BS 8	1.8	1.8	Coarse-grained crystalline medium-gray limestone with some large calcite-replaced fossils. Ledge former.
	0.6	2.4	Covered interval
BS 9	0.6	3.0	Fine-grained to medium-grained medium-gray crystalline limestone. Forms a ledge.
	0.6	3.6	Covered interval
	0.6	4.2	Fine-grained to medium-grained medium-gray crystalline limestone. Forms a ledge.
	1.0	5.2	Covered interval
	0.3	5.5	Fine-grained to medium-grained medium-gray crystalline limestone. Forms a ledge.
	0.6	6.1	Covered interval
	0.3	6.4	Fine-grained crystalline limestone at bottom, coarse-grained crystalline limestone at top. Medium-gray. Some coarse fossil fragments. Forms a ledge.
	3.0	9.4	Covered interval
	1.5	10.9	Fine-grained light-gray silty limestone, grading up to fine-grained medium-gray to dark-gray unsilty limestone. Forms a prominent ledge.
	1.0	11.9	Covered interval
BS 12	0.6	12.5	Fine-grained medium gray to light-gray limestone, slightly silty. Few large fossil fragments, some chert nodules. Forms a ledge.

Bed #	Thickness in meters	Cumulative thickness in meters	Description
	0.5	13.0	Fine-grained dark-gray limestone. One dense black chert bed, 15 cm thick. Forms a ledge.
	1.5	14.5	Covered interval
BS 13	1.8	16.3	Fine-grained to medium-grained pinkish-weathering siltstone. Forms a ledge.
	0.6	16.9	Medium-grained dark-gray limestone. Forms a ledge.
	0.6	17.5	Covered interval
	0.6	18.1	Fine-grained slightly silty light-gray limestone. Forms a small ledge.
	1.5	19.6	Covered interval
	1.2	20.8	Fine-grained slightly silty dark-gray limestone with some chert nodules and beds. One 15 cm layer of calcite replaced brachiopods, 15 cm from top of bed. Ledge former.
BS 14	3.6	24.4	Fine-grained pink-brown weathering siltstone. Slope former.
	4.2	28.6	Covered interval
	1.0	29.6	Fine-grained to medium-grained light-gray to medium-gray limestone. Dense black chert layer at top, one bed of brachiopods present in center of bed. Forms a small ledge.
	1.5	31.1	Covered interval
BS 15	0.3	31.4	Fine-grained medium-gray limestone. Forms small ledge.
	6.0	37.4	Medium-grained medium-gray limestone with chert. Ledge.

Bed #	Thickness in meters	Cumulative thickness in meters	Description
	3.0	40.4	Covered interval
	2.4	42.8	Fine-grained light-gray limestone. Some chert nodules, a few layers of brachiopods. Ledge and slope former.
	3.0	45.8	Fine-grained to medium-grained dark-gray to medium-gray limestone. Chert is common. Forms slopes and ledges.
	1.5	47.3	Covered interval
	4.5	51.8	Fine-grained to medium-grained dark-gray to medium-gray limestone. Contains some concentrically layered chert and a few layers of coarse fossil fragments, including Brachiopods. Forms ledges.
	3.0	54.8	Covered interval
BS 16	6.0	60.8	Alternating layers of brown chert and light-gray to medium-gray limestone. Chert seen both as beds and as hollow balls, 5 cm diam. Brachiopod fragments are present. Forms a cliff.
	1.2	62.0	Covered interval
	1.0	63.0	Fine-grained light-gray silty limestone with some beds of brachiopods and crinoid stems. Forms a small ledge.
	5.4	68.4	Covered interval
	4.5	72.9	Fine-grained blue-gray limestone with many layers of dark-gray dense chert pods. Very pure, semi-crystalline. Cliff former.
BS 17	3.0	75.9	Fine-grained pink and orange-weathering siltstone. Few Chert nodules. Fresh surface is dark-gray. Forms slopes.

Bed #	Thickness in meters	Cumulative thickness in meters	Description
	22.5	98.4	Fine-grained to medium-grained blue-gray very cherty semi-crystalline limestone. No silt. Forms massive cliffs.
	2.4	100.8	Fine-grained to medium-grained medium-gray limestone with several beds of orange-brown chert balls. Smells of sulphur when freshly broken.
	1.5	102.3	Covered interval
BS 20, 21	4.5	106.8	Fine-grained light-gray to medium-gray slightly silty limestone with 3 cm thick chert beds accentuating large-scale cross-stratification. Cliff former.
BS 19	9.0	115.8	Fine-grained semi-crystalline blue-gray limestone. Few beds of chert nodules. Some beds contain coarse fossil hash. Forms Ledges and slopes.
BS 22	3.0	118.8	Medium-grained medium-gray limestone with abundant chert nodules and beds. Some layers contain coarse fossil hash. Forms cliffs.
	1.5	120.3	Covered interval
BS 23	1.8	122.1	Fine-grained semi-crystalline medium-gray limestone with large chert-replaced colonial corals. Ledge former.
	1.5	123.6	Covered interval
	1.5	129.2	Fine-grained medium-gray limestone, weathers rough and craggy. One brown chert bed in middle, 0.5 m thick. Forms a small cliff.
	1.5	126.6	Covered interval
BS 24	2.1	128.7	Fine-grained light-blue-gray limestone, few fossil hash. Dark gray chert in beds and nodules. Some chert replaced colonial coral. Forms a ledge.

Bed #	Thickness in meters	Cumulative thickness in meters	Description
	6.0	134.7	Fine-grained light-gray limestone with dark-gray chert nodules. Slope former.
	1.0	135.7	Medium-grained light-gray to medium-gray limestone with several beds of dense brown chert.
BS 25	1.5	137.2	Fine-grained orange-brown-weathering siltstone with chert nodules. Slope former.
BS 26	0.3	137.5	Coarse-grained tan-weathering semi-crystalline fossil hash. Ledge former.
BS 27	4.5	142.0	Fine-grained light-gray silty-weathering limestone with many chert nodules. Ledge former.
BS 28	4.5	146.5	Medium-grained medium-gray limestone with several beds of coarse grainstone. Some chert-replaced fossil fragments. Forms a cliff.
	1.5	148.0	Covered interval
	4.0	152.0	Coarse-grained medium-gray limestone with beds of fossil hash. Chert nodules and beds are common. Forms a cliff.
	3.0	155.0	Covered interval